The Journal of Experimental Biology

Volume 199 1996

Editor in Chief R. G. Boutilier (Cambridge)

Editors M. Burrows (Cambridge), H. Hoppeler (Berne), N. Nelson (Tel Aviv) and G. N. Somero (California)

Review Editor W. R. Harvey (Philadelphia)

Assistant Editors A. J. Cooper, E. A. Howes and D. Powell (Cambridge)

Editorial Assistant S. K. Ray (Cambridge)

Editorial Advisory Board

R. McN. Alexander (Leeds)
M. J. Berridge (Cambridge)
V. E. Dionne (Woods Hole)
T. Eisner (Cornell)
C. P. Ellington (Cambridge)
J. M. Gosline (British Columbia)
M. Grieshaber (Düsseldorf)
D. R. Jones (British Columbia)
R. K. Josephson (Irvine)
G. V. Lauder (Irvine)
H. A. Lester (Pasadena)
C. P. Mangum (Williamsburg)
E. Marder (Brandeis)
H. Murer (Zurich)
J. G. Nicholls (Basel)
M. Nikinmaa (Turku)
S. Nilsson (Gothenborg)
U. M. Norberg (Gothenborg)
K. Takahashi (Tokyo)
J. Weeks (Oregon)
R. Wehner (Zurich)
H. Wieczorek (Munich)
C. M. Wood (Ontario)

Published by The Company of Biologists Limited, Cambridge

The Company of Biologists Limited, founded in 1925, is a 'Company Limited by Guarantee' having tax-exempt charitable status. There is a Board of Directors consisting of about 20 professional biologists, two of them appointed annually by the Society for Experimental Biology, who receive no salary or fees for their services. The Company's main function is to own and produce *The Journal of Experimental Biology*, the *Journal of Cell Science* and *Development*, and to appoint the Editors of these journals. These are part-time appointments held by established professional biologists of some eminence, and once they have been appointed the Company exercises no control over editorial policy.

The Company is precluded by its charitable status from making a commercial profit on its operations, and its aim is to produce high-quality journals at the lowest possible price. Any surplus on publishing not required for the journals' reserves is transferred to an Educational Trust Fund, which makes substantial grants in aid of societies concerned with the fields of interest covered by the Company's journals. Grants are also made to conferences and summer schools in the fields of its journals.

Typeset, Printed and Published by
The Company of Biologists Limited
Bidder Building, 140 Cowley Road, Cambridge CB4 4DL, UK

© The Company of Biologists Limited 1996

Contents

Volume 199 1996

SECTION 1. Large-scale navigation: long-distance migration in the sea and across land

Able, K. P.
Large-scale navigation 1–2

Able, K. P. and Able, M. A.
The flexible migratory orientation system of the Savannah sparrow (*Passerculus sandwichensis*) 3–8

Alerstam, T.
The geographical scale factor in orientation of migrating birds 9–19

Walcott, C.
Pigeon homing: observations, experiments and confusions 21–27

Wiltschko, W. and Wiltschko, R.
Magnetic orientation in birds 29–38

Gwinner, E.
Circadian and circannual programmes in avian migration 39–48

Helbig, A. J.
Genetic basis, mode of inheritance and evolutionary changes of migratory directions in palaearctic warblers (Aves: Sylviidae) 49–55

Klaassen, M.
Metabolic constraints on long-distance migration in birds 57–64

Papi, F. and Luschi, P.
Pinpointing 'Isla Meta': the case of sea turtles and albatrosses 65–71

Lohmann, K. J. and Lohmann, C. M. F.
Orientation and open-sea navigation in sea turtles 73–81

Dittman, A. H. and Quinn, T. P.
Homing in Pacific salmon: mechanisms and ecological basis 83–91

Brower, L. P.
Monarch butterfly orientation: missing pieces of a magnificent puzzle 93–103

The olfactory map hypothesis of pigeon navigation

Wallraff, H. G.
Seven theses on pigeon homing deduced from empirical findings 105–111

Wiltschko, R.
The function of olfactory input in pigeon orientation: does it provide navigational information or play another role? 113–119

Able, K. P.
The debate over olfactory navigation by homing pigeons 121–124

SECTION 2. Middle-scale navigation: searching for food and returning home within an animal's foraging range

Wehner, R.
Middle-scale navigation: the insect case 125–127

Wehner, R., Michel, B. and Antonsen, P.
Visual navigation in insects: coupling of egocentric and geocentric information 129–140

Menzel, R., Geiger, K., Chittka, L., Joerges, J., Kunze, J. and Müller, U.
The knowledge base of bee navigation 141–146

Dyer, F. C.
Spatial memory and navigation by honeybees on the scale of the foraging range 147–154

Esch, H. E. and Burns, J. E.
Distance estimation by foraging honeybees 155–162

Sherry, D. F.
Middle-scale navigation: the vertebrate case 163–164

Sherry, D. F. and Duff, S. J.
Behavioural and neural bases of orientation in food-storing birds 165–171

McNaughton, B. L., Barnes, C. A., Gerrard, J. L., Gothard, K., Jung, M. W., Knierim, J. J., Kudrimoti, H., Qin, Y., Skaggs, W. E., Suster, M. and Weaver, K. L.
Deciphering the hippocampal polyglot: the hippocampus as a path integration system 173–185

Biegler, R. and Morris, R. G. M.
Landmark stability: studies exploring whether the perceived stability of the environment influences spatial representation 187–193

Galea, L. A. M., Kavaliers, M. and Ossenkopp, K.-P.
Sexually dimorphic spatial learning in meadow voles *Microtus pennsylvanicus* and deer mice *Peromyscus maniculatus* 195–200

Etienne, A. S., Maurer, R. and Séguinot, V.
Path integration in mammals and its interaction with visual landmarks 201–209

Gallistel, C. R. and Cramer, A. E.
Computations on metric maps in mammals: getting oriented and choosing a multi-destination route 211–217

Bennett, A. T. D.
Do animals have cognitive maps? 219–224

SECTION 3. Small-scale navigation: pinpointing the goal

Collett, T. S.
Short-range navigation: does it contribute to understanding navigation over longer distances? 225–226

Collett, T. S.
Insect navigation *en route* to the goal: multiple strategies for the use of landmarks 227–235

Srinivasan, M. V., Zhang, S. W., Lehrer, M. and Collett, T. S.
Honeybee navigation *en route* to the goal: visual flight control and odometry 237–244

Zeil, J., Kelber, A. and Voss, R.
Structure and function of learning flights in ground-nesting bees and wasps 245–252

Lehrer, M.
Small-scale navigation in the honeybee: active acquisition of visual information about the goal 253–261

Tobalske, B. W. and Dial, K. P.
Flight kinematics of black-billed magpies and pigeons over a wide range of speeds 263–280

Okamoto, M., Yasuda, K. and Azuma A.
Aerodynamic characteristics of the wings and body of a dragonfly 281–294

Yoshimura, K.
A novel type of mechanoreception by the flagella of *Chlamydomonas* 295–302

Shoji, T., Fujita, K.-I., Furihata, E. and Kurihara, K.
Olfactory responses of a euryhaline fish, the rainbow trout: adaptation of olfactory receptors to sea water and salt-dependence of their responses to amino acids 303–310

Miller, R. L. and Vogt, R.
An N-terminal partial sequence of the 13 kDa *Pycnopodia helianthoides* sperm chemoattractant 'startrak' possesses sperm-attracting activity 311–318

Sadrud-Din, S., Loeb, M. J. and Hakim, R. S.
In vitro differentiation of isolated stem cells from the midgut of *Manduca sexta* larvae 319–325

Schmidt, J., Mangold, C. and Deitmer, J. W.
Membrane responses evoked by organic buffers in identified leech neurones 327–335

Hammond, K. A., Lloyd, K. C. K. and Diamond, J.
Is mammary output capacity limiting to lactational performance in mice? 337–349

Schaeffer, P. J., Conley, K. E. and Lindstedt, S. L.
Structural correlates of speed and endurance in skeletal muscle: the rattlesnake tailshaker muscle 351–358

Axelsson, M., Franklin, C. E., Löfman, C. O., Nilsson, S. and Grigg, G. C.
Dynamic anatomical study of cardiac shunting in crocodiles using high-resolution angioscopy 359–365

Kostron, B., Kaltenhauser, U., Seibel, B., Bräunig, P. and Honegger, H. W.
Localization of bursicon in CCAP-immunoreactive cells in the thoracic ganglia of the cricket *Gryllus bimaculatus* 367–377

Gulinson, S. L. and Harrison, J. F.
Control of resting ventilation rate in grasshoppers 379–389

Krolikowski, K. and Harrison, J. F.
Haemolymph acid–base status, tracheal gas levels and the control of post-exercise ventilation rate in grasshoppers 391–399

Johnsson, M., Axelsson, M., Davison, W., Forster, M. E. and Nilsson, S.
Effects of preload and afterload on the performance of the *in situ* perfused portal heart of the New Zealand hagfish *Eptatretus cirrhatus* 401–405

Just, F. and Walz, B.
The effects of serotonin and dopamine on salivary secretion by isolated cockroach salivary glands 407–413

Gallardo Romero, M., Guizouarn, H., Pellissier, B., Garcia-Romeu, F. and Motais, R.
The erythrocyte Na^+/H^+ exchangers of eel (*Anguilla anguilla*) and rainbow trout (*Oncorhynchus mykiss*): a comparative study 415–426

Hentschel, U., Hand, S. C. and Felbeck, H.
The contribution of nitrate respiration to the energy budget of the symbiont-containing clam *Lucinoma aequizonata*: a calorimetric study 427–433

Bonser, R. H. C. and Rayner, J. M. V.
Measuring leg thrust forces in the common starling 435–439

Sakamoto, K., Hisatomi, O., Tokunaga, F. and Eguchi, E.
Two opsins from the compound eye of the crab *Hemigrapsus sanguineus* 441–450

Wolf, B. O. and Walsberg, G. E.
Respiratory and cutaneous evaporative water loss at high environmental temperatures in a small bird 451–457

Coughlin, D., Valdes, L. and Rome, L. C.
Muscle length changes during swimming in scup: sonomicrometry verifies the anatomical high-speed cine technique 459–463

Mugnano, J. A., Lee , R. E. and Taylor, R. T.
Fat body cells and calcium phosphate spherules induce ice nucleation in the freeze-tolerant larvae of the gall fly *Eurosta solidaginis* (Diptera, Tephritidae) 465–471

Neufeld, D. S. and Wright, S. H.
Response of cell volume in *Mytilus* gill to acute salinity change 473–484

Bernier, N. J., Harris, J., Lessard, J. and Randall, D. J.
Adenosine receptor blockade and hypoxia-tolerance in rainbow trout and Pacific hagfish. I. Effects on anaerobic metabolism 485–495

Bernier, N. J., Fuentes, J. and Randall, D. J.
Adenosine receptor blockade and hypoxia-tolerance in rainbow trout and Pacific hagfish. II. Effects on plasma catecholamines and erythrocytes 497–507

Teague , W. E., Golding, E. M. and Dobson, G. P.
Adjustment of K′ for the creatine kinase, adenylate kinase and ATP hydrolysis equilibria to varying temperature and ionic strength 509–512

Review

Maeda, M., Kubo, K., Nishi, T. and Futai, M.
Roles of gastric GATA DNA-binding proteins 513–520

Murayama, M. and Takahata, M.
Sensory control mechanisms of the uropod equilibrium reflex during walking in the crayfish *Procambarus clarkii* 521–528

Marden, J. H., Kramer, M. G. and Frisch, J.
Age-related variation in body temperature, thermoregulation and activity in a thermally polymorphic dragonfly 529–535

Alshuaib, W. B. and Byerly, L.
Modulation of membrane currents by cyclic AMP in cleavage-arrested *Drosophila* neurons 537–548

Perry, S. F., Reid, S. G. and Salama, A.
The effects of repeated physical stress on the β-adrenergic response of the rainbow trout red blood cell 549–562

Levi, R. and Camhi, J. M.
Producing directed behaviour: muscle activity patterns of the cockroach escape response 563–568

Airriess, C. N. and McMahon, B. R.
Short-term emersion affects cardiac function and regional haemolymph distribution in the crab *Cancer magister* 569–578

El Haj, A. J., Clarke, S. R., Harrison, P. and Chang, E. S.
In vivo muscle protein synthesis rates in the American lobster *Homarus americanus* during the moult cycle and in response to 20-hydroxyecdysone 579–585

Farley, C. T. and Emshwiller, M.
Efficiency of uphill locomotion in nocturnal and diurnal lizards 587–592

Curtin, N. A. and Woledge, R. C.
Power at the expense of efficiency in contraction of white muscle fibres from dogfish *Scyliorhinus canicula* 593–601

Nilsson, G. E.
Brain and body oxygen requirements of *Gnathonemus petersii*, a fish with an exceptionally large brain 603–607

Kram, R.
Inexpensive load carrying by rhinoceros beetles 609–612

Jellema, T. and Heitler, W. J.
Peripheral control of the gain of a central synaptic connection between antagonistic motor neurones in the locust 613–625

De Wachter, B. and McMahon, B. R.
Haemolymph flow distribution, cardiac performance and ventilation during moderate walking activity in *Cancer magister* (Dana) (Decapoda, Crustacea) 627–633

Thamotharan, M. and Ahearn, G. A.
Dipeptide transport by crustacean hepatopancreatic brush-border membrane vesicles 635–641

Duerr, J. M. and Ahearn, G. A.
Characterization of a basolateral electroneutral Na^+/H^+ antiporter in Atlantic lobster (*Homarus americanus*) hepatopancreatic epithelial vesicles 643–651

Ocker, W.-G. and Hedwig, B.
Interneurones involved in stridulatory pattern generation in the grasshopper *Chorthippus mollis* (Charp.) 653–662

Farrell, A. P., Gamperl, A. K., Hicks, J. M. T., Shiels, H. A. and Jain, K. E.
Maximum cardiac performance of rainbow trout (*Oncorhynchus mykiss*) at temperatures approaching their upper lethal limit 663–672

Hjelmstad, G. O., Parks, G. and Bodznick, D.
Motor corollary discharge activity and sensory responses related to ventilation in the skate vestibulolateral cerebellum: implications for electrosensory processing 673–681

Lukowiak, K., Ringseis, E., Spencer, G., Wildering, W. and Syed, N.
Operant conditioning of aerial respiratory behaviour in *Lymnaea stagnalis* 683–691

McKean, T. and Mendenhall, W.
Comparison of the responses to hypoxia, ischaemia and ischaemic preconditioning in wild marmot and laboratory rabbit hearts 693–697

Ali, D. W. and Orchard, I.
The uptake and release of serotonin and dopamine associated with locust (*Locusta migratoria*) salivary glands 699–709

Ando, M. and Nagashima, K.
Intestinal Na^+ and Cl^- levels control drinking behavior in the seawater-adapted eel *Anguilla japonica* 711–716

Denny, M. and Gaylord, B.
Why the urchin lost its spines: hydrodynamic forces and survivorship in three echinoids 717–729

Brackenbury, J.
Targetting and optomotor space in the leaf-hopper *Empoasca vitis* (Gothe) (Hemiptera: Cicadellidae) 731–740

Review

Ehrengruber, M. U., Deranleau, D. A. and Coates, T. D.
Shape oscillations of human neutrophil leukocytes: characterization and relationship to cell motility 741–747

Truman, J. W., Ewer, J. and Ball, E. E.
Dynamics of cyclic GMP levels in identified neurones during ecdysis behaviour in the locust *Locusta migratoria* 749–758

Johnston, R. M. and Levine, R. B.
Locomotory behavior in the hawkmoth *Manduca sexta*: kinematic and electromyographic analyses of the thoracic legs in larvae and adults 759–774

Sandstrom, D. J. and Weeks, J. C.
Novel dual innervation of a larval proleg muscle by two similar motoneurons in the tobacco hornworm *Manduca sexta* 775–791

Ramachandran, A. V., Patel, M. M. and Patel, C. S.
Effects of pineal indoles and parachlorophenylalanine on seasonal reproduction in the pigeon 793–800

Prilutsky, B. I., Herzog, W. and Allinger, T. L.
Mechanical power and work of cat soleus, gastrocnemius and plantaris muscles during locomotion: possible functional significance of muscle design and force patterns 801–814

Stinner, J. N., Grguric, M. R. and Beaty, S. L.
Ventilatory and blood acid–base adjustments to a decrease in body temperature from 30 to 10 °C in black racer snakes *Coluber constrictor* 815–823

Spierts, I. L. Y., Akster, H. A., Vos, I. H. C. and Osse, J. W. M.
Local differences in myotendinous junctions in axial muscle fibres of carp (*Cyprinus carpio* L.) 825–833

Taylor, S. E., Egginton, S. and Taylor, E. W.
Seasonal temperature acclimatisation of rainbow trout: cardiovascular and morphometric influences on maximal sustainable exercise level 835–845

Waters, D. A. and Jones, G.
The peripheral auditory characteristics of noctuid moths: responses to the search-phase echolocation calls of bats 847–856

Waters, D. A.
The peripheral auditory characteristics of noctuid moths: information encoding and endogenous noise 857–868

Flamarique, I. N. and Hawryshyn, C. W.
Retinal development and visual sensitivity of young Pacific sockeye salmon (*Oncorhynchus nerka*) 869–882

Weis, V. M. and Levine, R. P.
Differential protein profiles reflect the different lifestyles of symbiotic and aposymbiotic *Anthopleura elegantissima*, a sea anemone from temperate waters 883–892

Montgomery, J., Bodznick, D. and Halstead, M.
Hindbrain signal processing in the lateral line system of the dwarf scorpionfish *Scopeana papillosus* 893–899

Onken, H.
Active and electrogenic absorption of Na^+ and Cl^- across posterior gills of *Eriocheir sinensis*: influence of short-term osmotic variations 901–910

Finke, E., Pörtner, H. O., Lee, P. G. and Webber, D. M.
Squid (*Lolliguncula brevis*) life in shallow waters: oxygen limitation of metabolism and swimming performance 911–921

Taylor, P. M., Kaur, S., Mackenzie, B. and Peter, G. J.
Amino-acid-dependent modulation of amino acid transport in *Xenopus laevis* oocytes 923–931

Tufts, B. L., Currie, S. and Kieffer, J. D.
Relative effects of carbonic anhydrase infusion or inhibition on carbon dioxide transport and acid–base status in the sea lamprey *Petromyzon marinus* following exercise 933–940

Spafford, J. D., Grigoriev, N. G. and Spencer, A. N.
Pharmacological properties of voltage-gated Na^+ currents in motor neurones from a hydrozoan jellyfish *Polyorchis penicillatus* 941–948

Smith, A. M.
Cephalopod sucker design and the physical limits to negative pressure 949–958

Wolf, T. J., Ellington, C. P., Davis, S. and Feltham, M. J.
Validation of the doubly labelled water technique for bumblebees *Bombus terrestris* (L.) 959–972

Culik, B. M., Pütz, K., Wilson, R. P., Allers, D., Lage, J., Bost, C. A. and Le Maho, Y.
Diving energetics in king penguins (*Aptenodytes patagonicus*) 973–983

Gosline, J. M. and Shadwick, R. E.
The mechanical properties of fin whale arteries are explained by novel connective tissue designs 985–997

Shashar, N. and Cronin, T. W.
Polarization contrast vision in *Octopus* 999–1004

Bell, E. C. and Gosline, J. M.
Mechanical design of mussel byssus: material yield enhances attachment strength 1005–1017

Jäger, D., Novak, F. J. S., Harvey, W. R., Wieczorek, H. and Klein, U.
Temporal and spatial distribution of V-ATPase and its mRNA in the midgut of moulting *Manduca sexta* 1019–1027

Tambutté, E., Allemand, D., Mueller, E. and Jaubert, J.
A compartmental approach to the mechanism of calcification in hermatypic corals 1029–1041

Kakizawa, S., Kaneko, T. and Hirano, T.
Elevation of plasma somatolactin concentrations during acidosis in rainbow trout (*Oncorhynchus mykiss*) 1043–1051

Meredith, J., Ring, M., Macins, A., Marschall, J., Cheng, N. N., Theilmann, D., Brock, H. W. and Phillips, J. E.
Locust ion transport peptide (ITP): primary structure, cDNA and expression in a baculovirus system 1053–1061

Stengl, M. and Zintl, R.
NADPH diaphorase activity in the antennae of the hawkmoth *Manduca sexta* 1063–1072

Smith, M. J. C., Wilkin, P. J. and Williams, M. H.
The advantages of an unsteady panel method in modelling the aerodynamic forces on rigid flapping wings 1073–1083

Wharton, D. A.
Water loss and morphological changes during desiccation of the anhydrobiotic nematode *Ditylenchus dipsaci* 1085–1093

Kingan, T. G., Shabanowitz, J., Hunt, D. F. and Witten, J. L.
Characterization of two myotrophic neuropeptides in the FMRFamide family from the segmental ganglia of the moth *Manduca sexta*: candidate neurohormones and neuromodulators 1095–1104

Christopher, K. J., Chang, J. P. and Goldberg, J. I.
Stimulation of ciliary beat frequency by serotonin is mediated by a Ca^{2+} influx in ciliated cells of *Helisoma trivolvis* embryos 1105–1113

Corotto, F. S., Piper, D. R., Chen, N. and Michel, W. C.
Voltage- and Ca^{2+}-gated currents in zebrafish olfactory receptor neurons 1115–1126

Kelber, A.
Colour learning in the hawkmoth *Macroglossum stellatarum* 1127–1131

Kasapi, M. A. and Gosline, J. M.
Strain-rate-dependent mechanical properties of the equine hoof wall 1133–1146

Supekova, L., Sbia, M., Supek, F., Ma, Y. and Nelson, N.
A novel subunit of vacuolar H^+-ATPase related to the *b* subunits of F-ATPases 1147–1156

Haman, F. and Weber, J.-M.
Continuous tracer infusion to measure *in vivo* metabolite turnover rates in trout 1157-1162

O'Donnell, M. J., Dow, J. A. T., Huesmann, G. R., Tublitz, N. J. and Maddrell, S. H. P.
Separate control of anion and cation transport in Malpighian tubules of *Drosophila melanogaster* 1163–1175

Loi, P. K., Saunders, R. G., Young, D. C. and Tublitz, N. J.
Peptidergic regulation of chromatophore function in the European cuttlefish *Sepia officinalis* 1177–1187

Innocenti, A., Bertolucci, C., Minutini, L. and Foà, A.
Seasonal variations of pineal involvement in the circadian organization of the ruin lizard *Podarcis sicula* 1189–1194

Zhuang, Z. and Ahearn, G. A.
Ca^{2+} transport processes of lobster hepatopancreatic brush-border membrane vesicles 1195–1208

Wainwright, P. C. and Turingan, R. G.
Muscular basis of buccal pressure: inflation behavior in the striped burrfish *Chilomycterus schoepfi* 1209–1218

Reilly, S. M.
The metamorphosis of feeding kinematics in *Salamandra salamandra* and the evolution of terrestrial feeding behavior 1219–1227

Shapiro, D. F.
Size-dependent neural integration between genetically different colonies of a marine bryozoan 1229–1239

Beason, R. C. and Semm, P.
Does the avian ophthalmic nerve carry magnetic navigational information? 1241–1244

Liu, H., Wassersug, R. J. and Kawachi, K.
A computational fluid dynamics study of tadpole swimming 1245–1260

Salleo, A., Musci, G., Barra, P. F. A. and Calabrese, L.
The discharge mechanism of acontial nematocytes involves the release of nitric oxide 1261–1267

Rhodes, J. D., Croghan, P. C. and Dixon, A. F. G.
Uptake, excretion and respiration of sucrose and amino acids by the pea aphid *Acyrthosiphon pisum* 1269–1276

Ettema, G. J. C.
Elastic and length–force characteristics of the gastrocnemius of the hopping mouse (*Notomys alexis*) and the rat (*Rattus norvegicus*) 1277–1285

Zachariassen, K. E., Olsen, A. J. and Aunaas, T.
The effect of formaldehyde exposure on the transmembrane distribution of free amino acids in muscles of *Mytilus edulis* 1287–1294

Nelson, J. A., Tang, Y. and Boutilier, R. G.
The effects of salinity change on the exercise performance of two Atlantic cod (*Gadus morhua*) populations inhabiting different environments 1295–1309

Guderley, H. and Johnston, I. A.
Plasticity of fish muscle mitochondria with thermal acclimation 1311–1317

Bury, N. R., Flik, G., Eddy, F. B. and Codd, G. A.
The effects of cyanobacteria and the cyanobacterial toxin microcystin-LR on Ca^{2+} transport and Na^+/K^+-ATPase in tilapia gills 1319–1326

Küppers, J. and Bunse, I.
A primary cation transport by a V-type ATPase of low specificity 1327–1334

Wuttke, W. A., Munsch, T. and Deitmer, J. W.
Inhibition of voltage-dependent Ca^{2+} influx by extracellular ATP in salivary cells of the leech *Haementeria ghilianii* 1335–1341

Kraus, D. W., Doeller, J. E. and Powell, C. S.
Sulfide may directly modify cytoplasmic hemoglobin deoxygenation in *Solemya reidi* gills 1343–1352

Frier, H. J., Edwards, E., Smith, C., Neale, S. and Collett, T. S.
Magnetic compass cues and visual pattern learning in honeybees 1353–1361

Ball, D. and Johnston, I. A.
Molecular mechanisms underlying the plasticity of muscle contractile properties with temperature acclimation in the marine fish *Myoxocephalus scorpius* 1363–1373

Tautz, J.
Honeybee waggle dance: recruitment success depends on the dance floor 1375–1381

Robertson, R. M., Kuhnert, C. T. and Dawson, J. W.
Thermal avoidance during flight in the locust *Locusta migratoria* 1383–1393

Gee, C. E. and Robertson R. M.
Recovery of the flight system following ablation of the tegulae in immature adult locusts 1395–1403

Wilson, R. J. A., Kristan, W. B., Jr and Kleinhaus, A. L.
An increase in activity of serotonergic Retzius neurones may not be necessary for the consummatory phase of feeding in the leech *Hirudo medicinalis* 1405–1414

Wilson, R. J. A., Skierczynski, B. A., Blackwood, S., Skalak, R. and Kristan, W. B., Jr
Mapping motor neurone activity to overt behaviour in the leech: internal pressures produced during locomotion 1415–1428

Johnsson, M. and Axelsson, M.
Control of the systemic heart and the portal heart of *Myxine glutinosa* 1429–1434

Hicks, J. W., Ishimatsu, A., Molloi, S., Erskin, A. and Heisler, N.
The mechanism of cardiac shunting in reptiles: a new synthesis 1435–1446

Review:

Moriyama, Y.
Membrane energization by proton pumps is important for compartmentalization of drugs and toxins: a new type of active transport 1447–1454

Carrier, D. R.
Function of the intercostal muscles in trotting dogs: ventilation or locomotion? 1455–1465

Labhart, T.
How polarization-sensitive interneurones of crickets perform at low degrees of polarization 1467–1475

Cruse, H. and Silva Saavedra, M. G.
Curve walking in crayfish 1477–1482

Joanisse, D. R. and Storey, K. B.
Oxidative stress and antioxidants in overwintering larvae of cold-hardy goldenrod gall insects 1483–1491

Glass, M. L., Branco, L. G. S., Antunes-Rodrigues, J. and Gutkowska, J.
Characterization of the atrial natriuretic factor system in lungs of the toad *Bufo paracnemis* 1493–1499

Ker, R. F.
The time-dependent mechanical properties of the human heel pad in the context of locomotion 1501–1508

Vijayan, M. M., Mommsen, T. P., Glémet, H. C. and Moon, T. W.
Metabolic effects of cortisol treatment in a marine teleost, the sea raven 1509–1514

Schwarzbaum, P. J., Bernabeu, R. O., Krumschnabel, G., Biasi, C. and Wieser, W.
Effect of chemical anoxia on protein kinase C and Na^+/K^+-ATPase in hepatocytes of goldfish (*Carassius auratus*) and rainbow trout (*Oncorhynchus mykiss*) 1515–1521

Glendinning, J. I.
Is chemosensory input essential for the rapid rejection of toxic foods? 1523–1534

Fonseca, P. J. and Hennig, R. M.
Phasic action of the tensor muscle modulates the calling song in cicadas 1535–1544

Riestenpatt, S., Onken, H. and Siebers, D.
Active absorption of Na^+ and Cl^- across the gill epithelium of the shore crab *Carcinus maenas*: voltage-clamp and ion-flux studies 1545–1554

Mészáros, M. and Morton, D. B.
Comparison of the expression patterns of five developmentally regulated genes in *Manduca sexta* and their regulation by 20-hydroxyecdysone *in vitro* 1555–1561

Signore, P. E. and Jones, D. R.
Autonomic nervous control of heart rate in muskrats during exercise in air and under water 1563–1568

Zeil, J. and Al-Mutairi, M. M.
The variation of resolution and of ommatidial dimensions in the compound eyes of the fiddler crab *Uca lactea annulipes* (Ocypodidae, Brachyura, Decapoda) 1569–1577

Webster, S. G.
Measurement of crustacean hyperglycaemic hormone levels in the edible crab *Cancer pagurus* during emersion stress 1579–1585

Williams, E. E. and Somero, G. N.
Seasonal-, tidal-cycle- and microhabitat-related variation in membrane order of phospholipid vesicles from gills of the intertidal mussel *Mytilus californianus* 1587–1596

Isaacson, L. C. and Nicolson, S. W.
Electrical transients in the cell-volume response to cyclic AMP of the tsetse fly Malpighian tubule 1597–1604

de Boeck, G., Nilsson, G. E., Vlaeminck, A. and Blust, R.
Central monoaminergic responses to salinity and temperature rises in common carp 1605–1611

Pennycuick, C. J.
Wingbeat frequency of birds in steady cruising flight: new data and improved predictions 1613–1618

Neufeld, D. S. and Wright, S. H.
Salinity change and cell volume: the response of tissues from the estuarine mussel *Geukensia demissa* 1619–1630

Meyer, J. and Elsner, N.
How well are frequency sensitivities of grasshopper ears tuned to species-specific song spectra? 1631–1642

Taylor, C. R., Weibel, E. R., Weber, J.-M., Vock, R., Hoppeler, H., Roberts, T. J. and Brichon, G.
Design of the oxygen and substrate pathways. I. Model and strategy to test symmorphosis in a network structure 1643–1649

Roberts, T. J., Weber, J.-M., Hoppeler, H., Weibel, E. R. and Taylor, C. R.
Design of the oxygen and substrate pathways. II. Defining the upper limits of carbohydrate and fat oxidation 1651–1658

Weber, J.-M., Roberts, T. J., Vock, R., Weibel, E. R. and Taylor, C. R.
Design of the oxygen and substrate pathways. III. Partitioning energy provision from carbohydrates 1659–1666

Weber, J.-M., Brichon, G., Zwingelstein, G., McClelland, G., Saucedo, C., Weibel, E. R. and Taylor, C. R.
Design of the oxygen and substrate pathways. IV. Partitioning energy provision from fatty acids 1667–1674

Vock, R., Weibel, E. R., Hoppeler, H., Ordway, G., Weber, J.-M. and Taylor, C. R.
Design of the oxygen and substrate pathways. V. Structural basis of vascular substrate supply to muscle cells 1675–1688

Vock, R., Hoppeler, H., Claassen, H., Wu, D. X. Y., Billeter, R., Weber, J.-M., Taylor, C. R. and Weibel, E. R.
Design of the oxygen and substrate pathways. VI. Structural basis of intracellular substrate supply to mitochondria in muscle cells 1689–1697

Weibel, E. R., Taylor, C. R., Weber, J.-M., Vock, R., Roberts, T. J. and Hoppeler, H.
Design of the oxygen and substrate pathways. VII. Different structural limits for oxygen and substrate supply to muscle mitochondria 1699–1709

Heide, G. and Götz, K. G.
Optomotor control of course and altitude in *Drosophila melanogaster* is correlated with distinct activities of at least three pairs of flight steering muscles 1711–1726

Herrel, A., Cleuren, J. and de Vree, F.
Kinematics of feeding in the lizard *Agama stellio* 1727–1742

Sanderson, S. L., Stebar, M. C., Ackermann, K. L., Jones, S. H., Batjakas, I. E. and Kaufman, L.
Mucus entrapment of particles by a suspension-feeding tilapia (Pisces: Cichlidae) 1743–1756

Novicki, A. and Weeks, J. C.
The initiation of pre-ecdysis and ecdysis behaviors in larval *Manduca sexta*: the roles of the brain, terminal ganglion and eclosion hormone 1757–1769

Gomez, G. and Atema, J.
Temporal resolution in olfaction: stimulus integration time of lobster chemoreceptor cells 1771–1779

Moser, H., Mair, N. and Fresser, F.
Extracellular Ca^{2+} and its effect on acid extrusion in the crayfish stretch receptor neurone 1781–1789

Wang, T. and Hicks, J. W.
Cardiorespiratory synchrony in turtles 1791–1800

Reipschläger, A. and Pörtner, H. O.
Metabolic depression during environmental stress: the role of extracellular *versus* intracellular pH in *Sipunculus nudus* 1801–1807

Withers, P. C. and Guppy, M.
Do Australian desert frogs co-accumulate counteracting solutes with urea during aestivation? 1809–1816

Thurmond, F. A. and Trotter, J. A.
Morphology and biomechanics of the microfibrillar network of sea cucumber dermis 1817–1828

Douglas, J. E., Mittal, C., Thomason, J. J. and Jofriet, J. C.
The modulus of elasticity of equine hoof wall: implications for the mechanical function of the hoof 1829–1836

Feder, M. E., Cartaño, N. V., Milos, L., Krebs, R. A. and Lindquist, S. L.
Effect of engineering *Hsp70* copy number on Hsp70 expression and tolerance of ecologically relevant heat shock in larvae and pupae of *Drosophila melanogaster* 1837–1844

Stillman, J. H. and Somero, G. N.
Adaptation to temperature stress and aerial exposure in congeneric species of intertidal porcelain crabs (genus *Petrolisthes*): correlation of physiology, biochemistry and morphology with vertical distribution 1845–1855

Fitzgerald, E. M., Djamgoz, M. B. A. and Dunbar, S. J.
Maintenance of the K^+ activity gradient in insect muscle compared in Diptera and Lepidoptera: contributions of metabolic and exchanger mechanisms 1857–1872

Uesaka, T.
Synergistic action of neuropeptide Y and adrenaline in the eel atrium 1873–1880

Perspective

Dudley, R. and Chai, P.
Animal flight mechanics in physically variable gas mixtures 1881–1885

Inoue, T., Takasaki, M., Lukowiak, K. and Syed, N. I.
Inhibition of the respiratory pattern-generating neurons by an identified whole-body withdrawal interneuron of *Lymnaea stagnalis* 1887–1898

Sandberg, R. and Pettersson, J.
Magnetic orientation of snow buntings (*Plectrophenax nivalis*), a species breeding in the high Arctic: passage migration through temperate-zone areas 1899–1905

McClelland, B. E., Wilczynski, W. and Ryan, M. J.
Correlations between call characteristics and morphology in male cricket frogs (*Acris crepitans*) 1907–1919

David, J. A. and Pitman, R. M.
Modulation of Ca^{2+} and K^+ conductances in an identified insect neurone by the activation of an α-bungarotoxin-resistant cholinergic receptor 1921–1930

Cheng, J.-Y., Davison, I. G. and DeMont, M. E.
Dynamics and energetics of scallop locomotion 1931–1946

Day, N. and Butler, P. J.
Environmental acidity and white muscle recruitment during swimming in the brown trout (*Salmo trutta*) 1947–1959

Cook, A.
Ontogeny of feeding morphology and kinematics in juvenile fishes: a case study of the cottid fish *Clinocottus analis* 1961–1971

Lundquist, C. T., Baines, R. A. and Bacon, J. P.
Evidence that histamine is a neurotransmitter in an insect extraocular photoreceptor pathway 1973–1982

Ettema, G. J. C.
Mechanical efficiency and efficiency of storage and release of series elastic energy in skeletal muscle during stretch–shorten cycles 1983–1997

Thomas, M. J., Hamman, B. N. and Tibbits, G. F.
Dihydropyridine and ryanodine binding in ventricles from rat, trout, dogfish and hagfish 1999–2009

Gronenberg, W., Heeren, S. and Hölldobler, B.
Age-dependent and task-related morphological changes in the brain and the mushroom bodies of the ant *Camponotus floridanus* 2011–2019

Gronenberg, W.
The trap-jaw mechanism in the dacetine ants *Daceton armigerum* and *Strumigenys* sp. 2021–2033

Giannessi, F., Fattori, B., Ruffoli, R. and Gagliardo, A.
Homing experiments on pigeons subjected to bilateral destruction of the paratympanic organ 2035–2039

Simon, T. W. and Barnes, K.
Olfaction and prey search in the carnivorous leech *Haemopis marmorata* 2041–2051

Richmond, J. E., Penner, R., Keller, R. and Cooke, I. M.
Characterization of the Ca^{2+} current in isolated terminals of crustacean peptidergic neurons 2053–2059

Herman, J. K. and Ingermann, R. L.
Effects of hypoxia and hyperoxia on oxygen-transfer properties of the blood of a viviparous snake 2061–2070

Chao, H., Davies, P. L. and Carpenter, J. F.
Effects of antifreeze proteins on red blood cell survival during cryopreservation 2071–2076

Shashar, N., Rutledge, P. S. and Cronin, T. W.
Polarization vision in cuttlefish – a concealed communication channel? 2077–2084

Dickinson, M. H. and Götz, K. G.
The wake dynamics and flight forces of the fruit fly *Drosophila melanogaster* 2085–2104

Perry, S. F. and Gilmour, K. M.
Consequences of catecholamine release on ventilation and blood oxygen transport during hypoxia and hypercapnia in an elasmobranch (*Squalus acanthias*) and a teleost (*Oncorhynchus mykiss*) 2105–2118

Review

Wang, T. and Hicks, J. W.
The interaction of pulmonary ventilation and the right–left shunt on arterial oxygen levels 2121–2129

Okano, K., Shimizu, K., Satuito, C. G. and Fusetani, N.
Visualization of cement exocytosis in the cypris cement gland of the barnacle *Megabalanus rosa* 2131–2137

Long, J. H., Jr, Hale, M. E., McHenry, M. J. and Westneat, M. W.
Functions of fish skin: flexural stiffness and steady swimming of longnose gar *Lepisosteus osseus* 2139–2151

Wilson, S. M., Rakhit, S., Murdoch, R., Pediani, J. D., Elder, H. Y., Baines, D. L., Ko, W. H. and Wong, P. Y. D.
Activation of apical P_{2U} purine receptors permits inhibition of adrenaline-evoked cyclic AMP accumulation in cultured equine sweat gland epithelial cells 2153–2160

Tornøe, C., Holden-Dye, L., Garland, C., Abramson, S. N., Fleming, J. T. and Sattelle, D. B.
Lophotoxin-insensitive nematode nicotinic acetylcholine receptors 2161–2168

Bässler, D., Büschges, A., Meditz, S. and Bässler, U.
Correlation between muscle structure and filter characteristics of the muscle–joint system in three orthopteran insect species 2169–2183

Bässler, U. and Stein, W.
Contributions of structure and innervation pattern of the stick insect extensor tibiae muscle to the filter characteristics of the muscle–joint system 2185–2198

Hemmersbach, R., Voormanns, R. and Häder, D.-P.
Graviresponses in *Paramecium biaurelia* under different accelerations: studies on the ground and in space 2199–2205

Hopkins, S. R., Wang, T. and Hicks, J. W.
The effect of altering pulmonary blood flow on pulmonary gas exchange in the turtle *Trachemys* (*Pseudemys*) *scripta* 2207–2214

Wilson, R. P. and Grémillet, D.
Body temperatures of free-living African penguins (*Spheniscus demersus*) and bank cormorants (*Phalacrocorax neglectus*) 2215–2223

Kinsey, S. T. and Ellington, W. R.
^{1}H- and ^{31}P-nuclear magnetic resonance studies of L-lactate transport in isolated muscle fibers from the spiny lobster *Panulirus argus* 2225–2234

Drucker, E. G. and Jensen, J. S.
Pectoral fin locomotion in the striped surfperch. I. Kinematic effects of swimming speed and body size 2235–2242

Drucker, E. G. and Jensen, J. S.
Pectoral fin locomotion in the striped surfperch. II. Scaling swimming kinematics and performance at a gait transition 2243–2252

Ferry, L. A. and Lauder, G. V.
Heterocercal tail function in leopard sharks: a three-dimensional kinematic analysis of two models 2253–2268

Gibb, A. C.
The kinematics of prey capture in *Xystreurys liolepis*: do all flatfish feed asymmetrically? 2269–2283

Chai, P. and Dudley, R.
Limits to flight energetics of hummingbirds hovering in hypodense and hypoxic gas mixtures 2285–2295

Kajiura, S. M. and Tricas, T. C.
Seasonal dynamics of dental sexual dimorphism in the Atlantic stingray *Dasyatis sabina* 2297–2306

Moore, A. and Waring, C. P.
Electrophysiological and endocrinological evidence that F-series prostaglandins function as priming pheromones in mature male Atlantic salmon (*Salmo salar*) parr 2307–2316

King, M. J., Buchmann, S. L. and Spangler, H.
Activity of asynchronous flight muscle from two bee families during sonication (buzzing) 2317–2321

Pierce, S. K., Biron, R. W. and Rumpho, M. E.
Endosymbiotic chloroplasts in molluscan cells contain proteins synthesized after plastid capture 2323–2330

Wilson, R. W., Gilmour, K. M., Henry, R. P. and Wood, C. M.
Intestinal base excretion in the seawater-adapted rainbow trout: a role in acid–base balance? 2331–2343

Review

Brown, D. and Breton, S.
Mitochondria-rich, proton-secreting epithelial cells 2345–2358

Brösamle, C. and Kuffler, D. P.
Rapid dispersal of clustered postsynaptic nuclei following dissociation of skeletal muscle fibers 2359–2367

Bässler, D. and Rathmayer, W.
Photoinactivation of an identified motoneurone in the locust *Locusta migratoria* 2369–2382

Shieh, K.-T., Wilson, W., Winslow, M., McBride, D. W. Jr and Hopkins, C. D.
Short-range orientation in electric fish: an experimental study of passive electrolocation 2383–2393

Elphick, M. R., Williams, L. and O'Shea, M.
New features of the locust optic lobe: evidence of a role for nitric oxide in insect vision 2395–2407

Sandeman, R. E. and Sandeman, D. C.
Pre- and postembryonic development, growth and turnover of olfactory receptor neurones in crayfish antennules 2409–2418

Lea, T. J.
Caffeine and micromolar Ca^{2+} concentrations can release Ca^{2+} from ryanodine-sensitive stores in crab and lobster striated muscle fibres 2419–2428

Winberg, S. and Nilsson, G. E.
Multiple high-affinity binding sites for [^{3}H]serotonin in the brain of a teleost fish, the Arctic charr (*Salvelinus alpinus*) 2429–2435

Büschges, A. and Wolf, H.
Gain changes in sensorimotor pathways of the locust leg 2437–2445

Nagayama, T., Aonuma, H. and Miyata, H.
GABA-like immunoreactivity of an identified nonspiking local interneurone in the crayfish terminal abdominal ganglion 2447–2450

Kaps, F. and Schmid, A.
Mechanism and possible behavioural relevance of retinal movements in the ctenid spider *Cupiennius salei* 2451–2458

Gallardo, M. A., Pesquero, J., Esteve, M., Canals, P. and Sánchez, J.
Regulation of the ASC system and Na^+/K^+ pump activities in brown trout (*Salmo trutta*) hepatocytes 2459–2465

Vijayan, M. M., Morgan, J. D., Sakamoto, T., Grau, E. G. and Iwama, G. K.
Food-deprivation affects seawater acclimation in tilapia: hormonal and metabolic changes 2467–2475

Madan, J. J. and Wells, M. J.
Cutaneous respiration in *Octopus vulgaris* 2477–2483

Bernier, N. J. and Perry, S. F.
Control of catecholamine and serotonin release from the chromaffin tissue of the Atlantic hagfish 2485–2497

Ritter, D.
Axial muscle function during lizard locomotion 2499–2510

Nishikawa, K. C. and Gans, C.
Mechanisms of tongue protraction and narial closure in the marine toad *Bufo marinus* 2511–2529

Benvenuti, S. and Gagliardo, A.
Homing behaviour of pigeons subjected to unilateral zinc sulphate treatment of their olfactory mucosa 2531–2535

Wang, S., Rubenfeld, A. B., Hayes, T. K. and Beyenbach, K. W.
Leucokinin increases paracellular permeability in insect Malpighian tubules 2537–2542

Hogstrand, C., Gassman, N. J., Popova, B., Wood, C. M. and Walsh, P. J.
The physiology of massive zinc accumulation in the liver of female squirrelfish and its relationship to reproduction 2543–2554

Review

Rasmussen, A. D. and Andersen, O.
Apparent water permeability as a physiological parameter in crustaceans 2555–2564

Murphy, K. P., Zhao, Y. and Kawai, M.
Molecular forces involved in force generation during skeletal muscle contraction 2565–2571

Takada, M., Yai, H., Komazaki, S. and Takayama-Arita, K.
Prolactin antagonizes the corticoid-promoted development of adult-type epidermis in cultured larval bullfrog skin 2573–2578

Jürgens, K. D., Fons, R., Peters, T. and Sender, S.
Heart and respiratory rates and their significance for convective oxygen transport rates in the smallest mammal, the Etruscan shrew *Suncus etruscus* 2579–2584

Sandeman, D. C., Tautz, J. and Lindauer, M.
Transmission of vibration across honeycombs and its detection by bee leg receptors 2585–2594

Law, T. C. and Blake, R. W.
Comparison of the fast-start performances of closely related, morphologically distinct threespine sticklebacks (*Gasterosteus* spp.) 2595–2604

Lowe, C. G.
Kinematics and critical swimming speed of juvenile scalloped hammerhead sharks 2605–2610

Glasheen, J. W. and McMahon, T. A.
Size-dependence of water-running ability in basilisk lizards (*Basiliscus basiliscus*) 2611–2618

Higgs, D. M. and Fuiman, L. A.
Ontogeny of visual and mechanosensory structure and function in Atlantic menhaden *Brevoortia tyrannus* 2619–2629

Baker, M. W., Chiasson, B. J. and Croll, R. P.
Contralateral sprouting and compensatory innervation following the permanent lesion of a ganglionic connective in the snail 2631–2643

Utter, B. D. and Denny, M. W.
Wave-induced forces on the giant kelp *Macrocystis pyrifera* (Agardh): field test of a computational model 2645–2654

De Jong, P. W., Gussekloo, S. W. S. and Brakefield, P. M.
Differences in thermal balance, body temperature and activity between non-melanic and melanic two-spot ladybird beetles (*Adalia bipunctata*) under controlled conditions 2655–2666

Ishimatsu, A., Hicks, J. W. and Heisler, N.
Analysis of cardiac shunting in the turtle *Trachemys* (*Pseudemys*) *scripta*: application of the three outflow vessel model 2667–2677

O'Brien, J. and Block, B. A.
Effects of Ca^{2+} on oxidative phosphorylation in mitochondria from the thermogenic organ of marlin 2679–2687

Pronych, S. P., Souza, K. A., Neff, A. W. and Wassersug, R. J.
Optomotor behaviour in *Xenopus laevis* tadpoles as a measure of the effect of gravity on visual and vestibular neural integration 2689–2701

Coughlin, D. J., Zhang, G. and Rome, L. C.
Contraction dynamics and power production of pink muscle of the scup (*Stenotomus chrysops*) 2703–2712

Rahaman-Noronha, E., O'Donnell, M. J., Pilley, C. M. and Wright, P. A.
Excretion and distribution of ammonia and the influence of boundary layer acidification in embryonic rainbow trout (*Oncorhynchus mykiss*) 2713–2723

Wells, P. R. and Pinder, A. W.
The respiratory development of Atlantic salmon. I. Morphometry of gills, yolk sac and body surface 2725–2736

Wells, P. R. and Pinder, A. W.
The respiratory development of Atlantic salmon. II. Partitioning of oxygen uptake among gills, yolk sac and body surfaces 2737–2744

Chai, P., Harrykissoon, R. and Dudley, R.
Hummingbird hovering performance in hyperoxic heliox: effects of body mass and sex 2745–2755

Pennycuick, C. J., Klaassen, M., Kvist, A. and Lindström, Å.
Wingbeat frequency and the body drag anomaly: wind-tunnel observations on a thrush nightingale (*Luscinia luscinia*) and a teal (*Anas crecca*) 2757–2765

Chan, W. P. and Dickinson, M. H.
In vivo length oscillations of indirect flight muscles in the fruit fly *Drosophila virilis* 2767–2774

Rajendran, R. R., Van Niel, E. E., Stenkamp, D. L., Cunningham, L. L., Raymond, P. A. and Gonzalez-Fernandez, F.
Zebrafish interphotoreceptor retinoid-binding protein: differential circadian expression among cone subtypes 2775–2787

Index of Authors 2789–2797

Index of Subjects 2799–2836